Name: ___________________________________

Marine Sediments Lab

(Adopted from an exercise developed by Professor Alan Trujillo, Palomar College)

The sea floor is composed of basalt that originates at mid-ocean ridges. However, the sea floor is covered in most places by layers of sediment. **Sediment** is defined as any accumulation of loose material. Examples: sand lying on a beach, mud at the bottom of a lake, or gravel lying on a river bed.

Large amounts of sediment are drained off the continents by rivers and glaciers, and blown out to sea by wind. Organisms in the surface waters provide a continuous supply of skeletal material that rains down onto the sea floor. Other sediments are formed in place by chemical reactions.

Because marine sediments accumulate under specific conditions, an understanding of modern sediment distributions can be used to interpret events in the geologic past, particularly for the last 200 million years of Earth's history (the maximum age of the ocean floor). **Sediment cores** are long cylinders of sediment brought up by ocean floor drilling. Oceanographers use these cores to look at the layers of sediment that have accumulated on the sea floor over time. Collectively, studies of cores reveal information about past climate, composition of atmospheric gases, evolution of animal and plant species, and movement of surface and deep water currents. The study of marine sediments is an important area of research in oceanography because of the keen interest in understanding changes in Earth’s atmosphere that are occurring now and have occurred in the past.

Classification of Marine Sediments

We classify marine sediments by their source. The four main types of sediment are **lithogenous**, **biogenous**, **hydrogenous** and **cosmogenous** (Table 1). In this lab, you will primarily examine lithogenous and biogenous sediments, because they are the most common and the most useful for reconstructing past events in the ocean basins.

Lithogenous Sediment

Lithogenous sediments (*lithos* = rock, *generare* = to produce) are sediments derived from erosion of rocks on the continents. A look at the “source” section of Table 1 illustrates the diversity of ways in which sediments from the continents enter the marine environment. **Rivers and glaciers** deliver large amounts of sediment the continental shelves. Through submarine canyons, **turbidity currents** can transport much of this material onto the continental rise and out onto the abyssal plains.

Although most lithogenous sediments accumulate along the continental margins, **winds** may blow small particles (clay, silt, and volcanic ash, for example) far out to sea. These particles settle slowly through the water and accumulate on the ocean floor. These small particles accumulate very slowly, at rates averaging 1 millimeter (0.04 inch) per 1000 years, which is equivalent to the size of the thickness of a dime. When these tiny particles settle in areas where little other material is being deposited (usually in deep-ocean basins), they form a sediment called **abyssal clay**.

TABLE 4.1 CLASSIFICATION OF MARINE SEDIMENTS

Type	Composition		Sources		Main locations found
Lithogenous	*Continental margin*	Rock fragments Quartz sand Quartz silt Clay		Rivers; coastal erosion; landslides	Continental shelf
				Glaciers	Continental shelf in high latitudes
				Turbidity currents	Continental slope and rise; ocean basin margins
	Oceanic	Quartz silt Clay		Wind-blown dust; rivers	Abyssal plains and other regions of the deep-ocean basins
		Volcanic ash		Volcanic eruptions	
Biogenous	*Calcium carbonate ($CaCO_3$)*	Calcareous ooze (microscopic)	*Warm surface waters*	Coccolithophores (algae) Foraminifers (protozoans)	Low-latitude regions; sea floor above CCD; along mid-ocean ridges and the tops of volcanic peaks
		Shells and coral fragments (macroscopic)		Macroscopic shell-producing organisms	Continental shelf; beaches
				Coral reefs	Shallow low-latitude regions
	Silica ($SiO_2 \cdot nH_2O$)	Siliceous ooze	*Cold surface waters*	Diatoms (algae) Radiolarians (protozoans)	High-latitude regions; sea floor below CCD; upwelling areas where cold, deep water rises to the surface, especially that caused by surface current divergence near the equator
Hydrogenous	Manganese nodules (manganese, iron, copper, nickel, cobalt)		Precipitation of dissolved materials directly from seawater due to chemical reactions		Abyssal plain
	Phosphorite (phosphorous)				Continental shelf
	Oolites ($CaCO_3$)				Shallow shelf in low-latitude regions
	Metal sulfides (iron, nickel, copper, zinc, silver)				Hydrothermal vents at mid-ocean ridges
	Evaporites (gypsum, halite, other salts)				Shallow restricted basins where evaporation is high in low-latitude regions
Cosmogenous	Iron–nickel spherules Tektites (silica glass)		Space dust		In very small proportions mixed with all types of sediment and in all marine environments
	Iron–nickel meteorites		Meteors		Localized near meteor impact structures

Table 1. Classification of the four main types of marine sediments showing composition, sources, and main locations found. From *Essentials of Oceanography* by Trujillo and Thurman, © Pearson Prentice Hall, Inc.

Biogenous Sediment

Biogenous sediments (*bio* = life, *generare* = to produce) are sediments made from the **skeletal remains of once-living organisms**. These hard parts include a wide variety of particles such as shells of microscopic organisms (called **tests**), coral fragments, sea urchin spines, and pieces of larger shells from organisms like clams and snails.

The most important type of biogenous sediment comes from the accumulation of tests of one-celled **microscopic algae and protozoans** living in the surface waters of the oceans. When these tests comprise greater than 30% of the particles, the sediment is called an **ooze**. Oozes are most abundant beneath open ocean areas where nutrients are available to enhance productivity. In these areas, oozes accumulate at an average rate of 1 centimeter (0.4 inch) per 1000 years. Oozes are generally absent on the continental margins where particles are predominantly lithogenous.

There are two major types of ooze based on the composition of the tests: **calcareous ooze** is made of calcium carbonate ($CaCO_3$); **siliceous ooze** is made of silica (SiO_2) or opal ($SiO_2 \cdot nH_2O$).

Calcareous ooze is composed of the tests of protozoans called **foraminifers (forams)**, and tiny algae called **coccolithophores**, which produce tiny plates called **coccoliths** (Figure 1). These calcite-secreting organisms are most productive in warm surface waters where seawater is saturated with calcium carbonate.

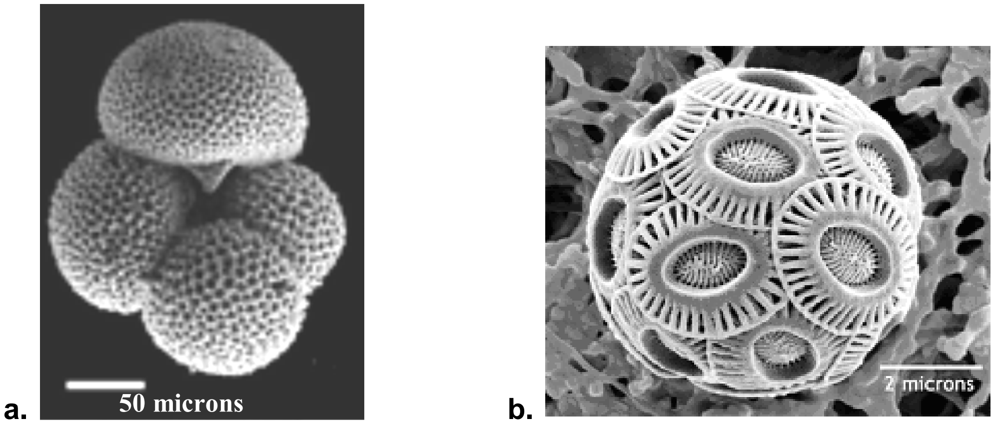


Figure 1. Examples of common microscopic calcite-secreting organisms. (a) A test from single-celled protozoan called a **foraminifer**. (b) A test from a single-celled algae called a **coccolithophore**, which has individual plates called coccoliths. The bars indicate scale; 1 micron equals 1 millionth of a meter or 0.00004 inch.

Deeper in the ocean, changes in temperature, pressure, and chemistry of the seawater cause calcareous tests to dissolve. At a certain depth, the tests dissolve faster than they accumulate, so calcareous oozes do not form below this depth; this depth is called the **calcite compensation depth (CCD)** (Figure 2). The depth of the CCD varies from one ocean basin to another, but on average occurs at approximately 4500 meters below sea level. The result is that calcareous oozes accumulate in areas above 4500 meters in the middle and low latitudes, usually on the mid-ocean ridges. In fact, there is a strong correlation between the locations of mid-ocean ridges and the distribution of calcareous ooze. As calcareous sediments are buried, they are subjected to increasing pressure and heat, which causes them to harden into **chalk**.

Siliceous ooze is made from the tests of algae called **diatoms** and protozoans called **radiolarians** (Figure 3). These organisms are most abundant in regions with high levels of nutrients and cold surface water. Siliceous oozes are typically found on the deep-sea floor where calcareous oozes are absent. Two major zones where siliceous oozes accumulate are in polar regions and beneath the zone of equatorial upwelling.

Hardened deposits of diatom-rich siliceous ooze and clay are referred to as **diatomaceous earth**, which is used in pool water filtration and a wide variety of other industrial applications.

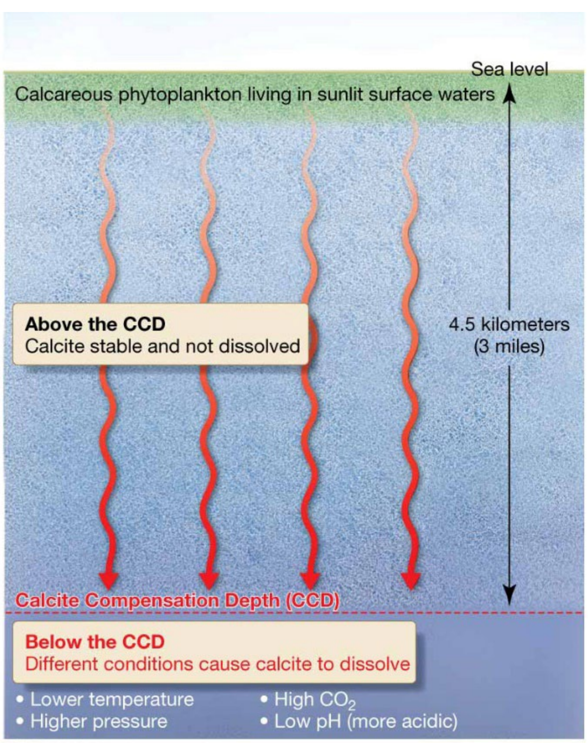
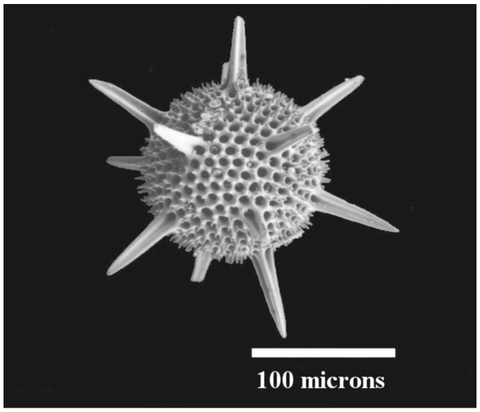


Figure 2. Schematic profile view of the ocean showing the calcite compensation depth (CCD). Above the CCD, calcite is stable and does not dissolve. Below the CCD, ocean conditions cause calcite to dissolve rapidly. From *Essentials of Oceanography* by Trujillo and Thurman, © Pearson Prentice Hall, Inc.

Not all silica from siliceous microorganisms winds up as siliceous ooze. In some cases, minor amounts of silica are deposited with calcareous ooze. Often this buried siliceous material combines to form hard rounded lumps or nodules called **chert nodules**. For example, the white cliffs of Dover (England) are made of chalk and also contain abundant chert nodules. Chert, a microcrystalline form of silica, is so hard that it is often used as a whetstone to sharpen knives.

a. 

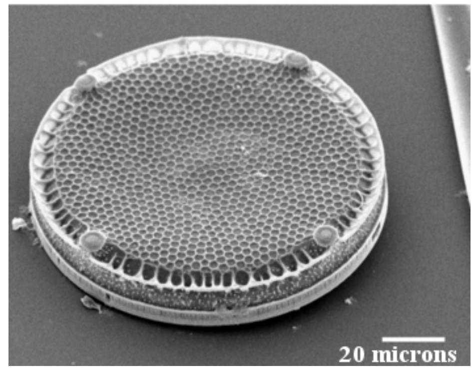
b. 

Figure 3. Examples of common microscopic silica-secreting organisms. (a) A test from a single-celled protozoan called a **radiolarian**. (b) A test from a single-celled algae called a **diatom**. The bars indicate scale; 1 micron equals 1 millionth of a meter or 0.00004 inch.

Hydrogenous Sediment

Hydrogenous sediments are created from chemical reactions in seawater. Under special chemical conditions, dissolved materials in seawater **precipitate** (form solids). Many types of hydrogenous sediments have economic value.

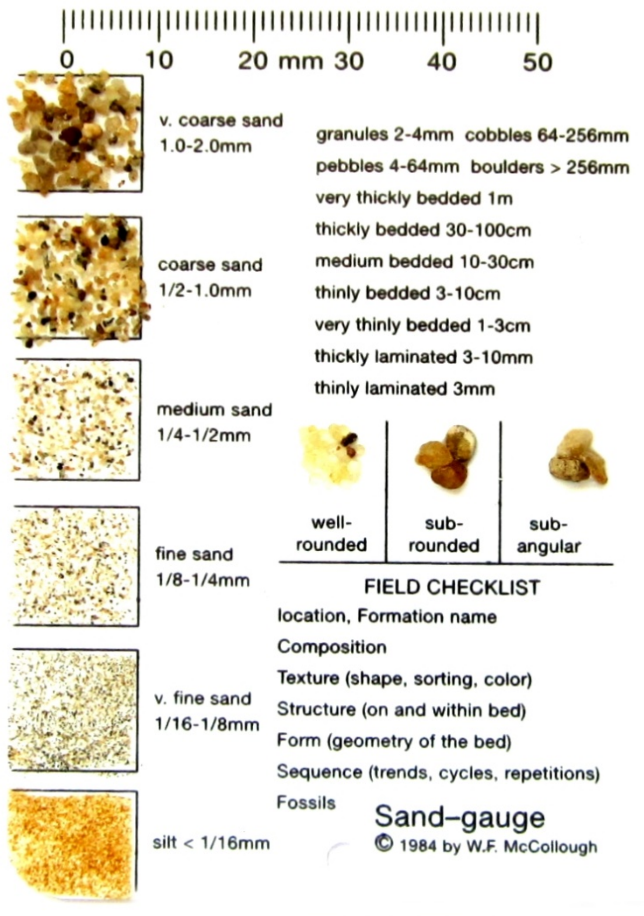
Hydrogenous sediments include **evaporites**, meaning any type of sediment that forms from the evaporation of seawater. As seawater evaporates, the ions that remain behind can become so concentrated that they will combine with one another to form crystals that precipitate. The two most common types of evaporates are gypsum and halite. **Gypsum** is hydrous calcium sulfate ($CaSO_4 \cdot 2H_2O$), and is mined worldwide to make fertilizer, plaster, and cement. **Halite** is sodium chloride ($NaCl$), which is common table salt. When you salt your food, you are eating the evaporated remains of ancient ocean water!

Manganese nodules are another type of hydrogenous sediment. They form golf ball- to tennis ball-sized lumps of iron and manganese oxide that lie scattered across the deep sea floor where sedimentation rates are particularly low. Although they contain large amounts of manganese, these nodules are economically most important for their cobalt, nickel, and chromium. Their formation is not well understood; however, we do know that they form as concentric layers (like an onion), adding layers of iron and manganese minerals slowly over time.

Oolites are a type of hydrogenous sediment that commonly forms beach sands in some tropical areas. Oolites (*oo* = egg, *ite* = stone) are sand-sized grains of calcium carbonate that precipitate out of seawater in warm, tropical waters such as in the Bahamas. Oolites need to roll back-and-forth to form, so they form only in shallow areas where waves cause back-and-forth motion on the seabed. The back-and-forth motion causes the grains to accrete layer after layer, somewhat like a snowball, so that each oolite has a spherical shape with a layered, onion-like internal structure.

Describing Sediment Characteristics

Lithogenous sediments exhibit characteristics that reflect the processes involved in their transportation and deposition. These characteristics are described as the sediment's **texture,** which includes the size and shape of the particles. For example, **grain size** is the size of the individual particles. In lab, you will use a chart like the one below to classify sediment samples by grain size.



Grain size generally indicates the **energy of the environment** in which the sediment accumulated. By "energy of the environment," we mean the ability of water, wind, or gravity to move the sediment particles. For example, a beach is a "high-energy" environment because the breaking waves and fast currents can move even large sediment particles, whereas the deep ocean floor is a "low-energy" environment because water movement is slow. Because it takes larger amounts of energy to transport larger grains, larger sized particles are often found closer to their original source. A river may carry a mixture of gravel, sand, silt, and clay; however, because the speed (energy) of the water decreases as the river flows into the ocean, much of the gravel and sand will settle out near the shoreline. In contrast, the silt and clay will be carried far out into the ocean and eventually settle in deep water (Figure 4). Another example is that beaches that are hit by lots of large waves tend to have larger-sized particles than beaches that experience smaller waves. The big waves carry away smaller particles, leaving only large particles behind.

The **rounding** of sand and gravel fragments is also an indication of the energy of the environment, or the time and/or distance the particles have been moved. On the chart above, notice the classifications of **well-rounded, subrounded,** and **sub-angular**. These terms refer to how round and smooth the particles are. Particles that are more rounded indicate greater wave energy (or other water motion), because the more particles are rolled around, the smoother and more rounded they become.

Accurate description and study of lithogenous sediments includes information on **grain size** and **rounding**. However, caution should be used when applying these characteristics to biogenous sediments. For example, the tests of some plankton organisms may start out round, and thus their roundness is not indicative of high wave energy.

Figure 4 below shows a hypothetical distribution of sediment types across a passive continental margin and adjacent ocean basin. Note that those sediments found close to the continent along the continental shelf are known as **neritic sediments** and are largely lithogenous. Those sediments found further from the continent are known as **pelagic sediments** and are often dominated by biogenous particles.

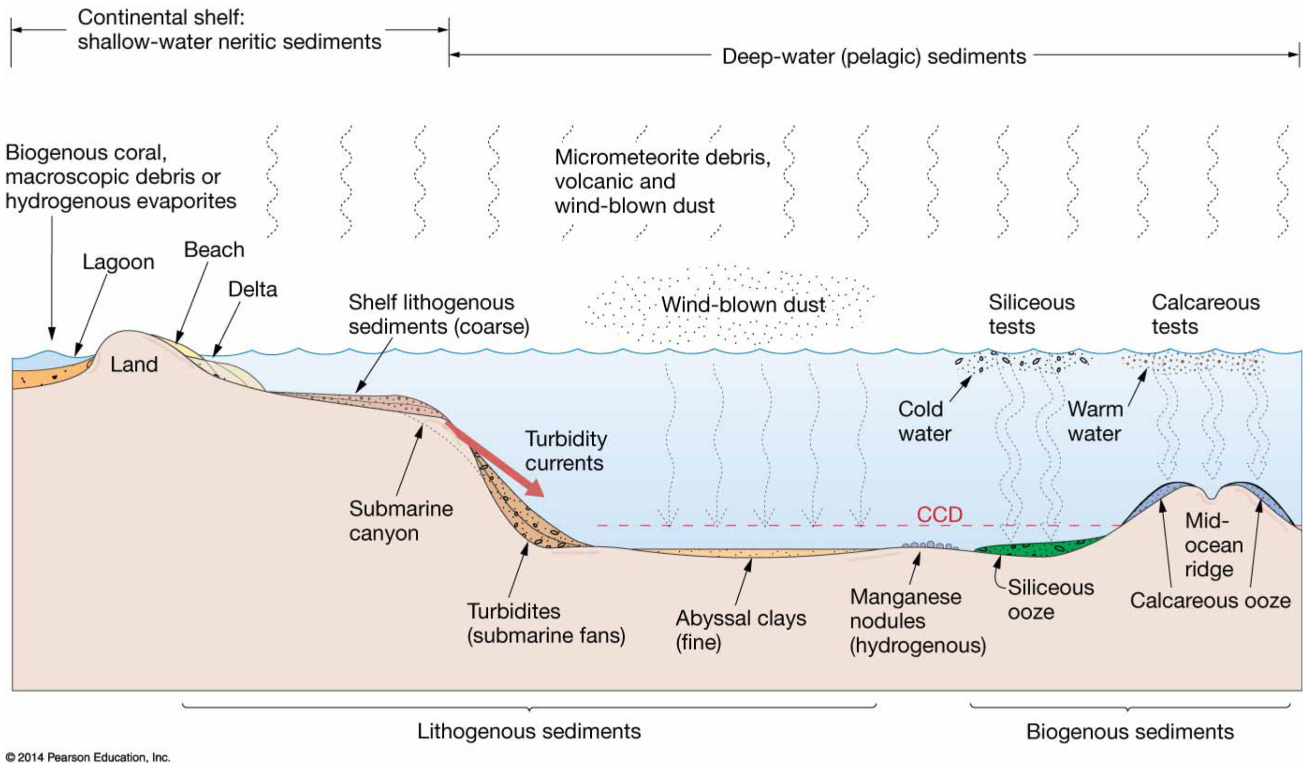


Figure 4. Schematic view of the distribution of various sediment types across an idealized passive margin and adjacent ocean basin. Note that with increasing distance from the continent that the grain size of lithogenous sediments decreases. From *Essentials of Oceanography* by Trujillo and Thurman, © Pearson Prentice Hall, Inc.

QUESTIONS

Answer the questions for of the following stations. You can do the stations in any order.

1. Del Mar Beach Sand

a. Examine this local beach sand and the accompanying rock and mineral samples. Estimate the abundance of each mineral in the sand sample using the "Percentage Composition" chart. Your total must equal 100%.

Mineral	**Percentage in Sample**
Quartz (clear, glassy grains; NOTE: it is greater than 50%)	
Feldspar (white, yellow, or pink) blocky grains	
Mica (flat black or golden flakes)	
Rock fragments (dark, blocky grains)	
TOTAL	**100%**

b. Which type of sediment is this? (circle one): ***lithogenous / biogenous / hydrogenous***

c. Use the grain size chart to determine the average grain size.

d. Classify the roundness of the grains using the chart provided.

e. Classify the sorting of the grains using the chart provided.

2. La Jolla Beach Sands

These samples from Point La Jolla and La Jolla Shores were collected at the same time. The map at this station shows the locations where the two samples were collected.

a. Use the grain size chart to determine the grain size of each sample.

Sample 2-1: Point La Jolla (circle one): ***very fine / fine / medium / coarse***

Sample 2-2: La Jolla Shores (circle one): ***very fine / fine / medium / coarse***

b. Based on the map, explain why there is a grain size difference between these two samples. *Hint: the answer relates to the differential **energy** of the two environments; see the information under "Describing Sediment Characteristics" several pages back.*

3. Encinitas Beach Sands

In 2012, a major dredging project added about 1.5 million cubic yards of new sand to San Diego County's beaches. As surveyors looked for dredge sites in shallow water offshore of the beach, they made an effort to find sand sources that were coarser–grained (meaning larger pieces) than the sand typically found on the beach.

a. Compare **sample 3-1** and **sample 3-2**. Which one is a sample of original beach sand, and which one is a sample of new dredged sand?

b. What advantage would there be dredge coarser-grained sand to add onto our beaches? Why not just use any sand available, whatever its size? *Hint: see the information under "Describing Sediment Characteristics" several pages back.*

You may have noticed, when visiting a local beach, that the sand is sometimes very dark and shiny. The dark color typically comes from high amounts of the magnetite, a common mineral in the rocks of San Diego's mountains. As the mountains erode, rivers transport the magnetite to the beach, along with other minerals, particularly quartz (as you saw at Station #1).

c. Hold the vial of magnetite and the vial of typical quartz-rich beach sand in your two hands. Which mineral—***magnetite*** or ***quartz***—(circle one) is denser (heavier for a given amount)?

d. You will usually find more magnetite-rich sand on the beach in winter than in summer. Why do you suppose this is so? *Hint: the size and power of waves that hit Southern California beaches is different in winter versus summer.*

4. Hawaiian Beach Sand I

This green-black sand is from a beach on the Big Island of Hawaii. The green mineral is **olivine**, a common mineral in volcanic basalt. *See the basalt rock sample containing olivine at this station.*

a. Describe what olivine looks like under the microscope.

b. Classify the roundness of the olivine grains. (Use the roundness chart provided.)

c. What percentage of the sand is olivine? ____________ % (Use the "Percent Composition" chart provided.)

d. The olivine and the fragments of basalt are from the erosion of volcanic lava beds. Sediments of this type are (circle one): ***lithogenous*** / ***biogenous*** / ***hydrogenous***

e. Hawaii is a tropical region known for its coral reefs. The white particles mixed in with the olivine and basalt are the broken remains corals and other shells. What percentage of the sand is shell fragments? ____________ %

f. Sediments produced from coral fragments and other shell materials are (circle one): ***lithogenous / biogenous / hydrogenous***

5. Hawaiian Beach Sand II

a. Compare these two sand samples under the microscopes, and use the grain cards and charts provided to complete the table.

	Sample 5-1: South Point, Big Island	**Sample 5-2: Oahu**
Grain size		
Roundness		
Sorting		
Composition (list the materials that make up the sand based on the descriptions below)		

Olivine: shiny green/yellow grains
Obsidian: shiny black, sharp-edged grains
Basalt fragments: dull black, blocky grains
Shell fragments: white, irregularly shaped grains

b. Based on the grain size, which beach has more wave energy? Explain.

c. Based on the composition, which beach is closer to a source of eroding volcanic rock?

6. Comparing beach sands: San Diego versus Hawaii

a. Compare these two sand samples under the microscopes, and use the grain cards and charts provided to complete the table.

	Sample 6-1: San Diego	**Sample 6-2: Hawaii**
Grain size		
Roundness		
Sorting		
Composition (list the materials that make up the sand, based on the descriptions below)		

Obsidian: shiny black, sharp-edged grains
Basalt or other rock fragments: dull black, blocky grains
Feldspar: white, yellow, or pink blocky grains
Quartz: clear, glassy grains
Mica: flat black or golden flakes

b. You have seen the difference in composition between the San Diego sand and the Hawaii sand. Both of these sands are **lithogenous**. Why is there such a big difference in composition? What types of rocks must have eroded to form San Diego's beach sand versus Hawaii's beach sand?

7. Oolites

a. Look at the oolites under magnification and describe what you see.

b. Describe how oolites form and how they get their spherical shape. *(Refer to the description given several pages back.)*

c. What type of sediment is this? (circle one): ***lithogenous / biogenous / hydrogenous***

8. Manganese nodules

Examine the manganese nodules, and notice their layered internal structure.

a. What type of sediment is this? (circle one): ***lithogenous / biogenous / hydrogenous***

b. How is the formation of manganese nodules similar to the formation of oolites? *(Hint: they have a similar internal structure; refer to the description given several pages back.)*

c. How is the formation of manganese nodules different from the formation of oolites? *(Hint: think about where they form; refer to the description given several pages back.)*

d. What economically valuable substances do manganese nodules contain?

9. Evaporite

This is one of two common types of **evaporite** sediment. Notice the cubic shape of the grains under the microscope. If you were to taste these (not required!), it would taste very familiar.

a. What type of sediment is this? (circle one): ***lithogenous / biogenous / hydrogenous***

b. What is the specific name of this evaporite, and how does it form?

10. Stars Sands

Some beaches in the western tropical Pacific, such as in Indonesia, have curious types of sand grains known as **"star sand."**

a. Scan this sample under the microscope to find star-shaped grains—you may need to move the sample around.. (Note: some of the "star" grains have been worn by wave abrasion.) Compare these star grains with the pictures in the "***Sands of the World***" article from *Scientific American* (in the 3-ring binder). Which sand pictured most resembles what you see? (circle one):

   Silver Sands Beach, Grand Bahamas

   Saint-Tropez, French Riviera

   Taketomi Shima, Ryukyu Islands, Japan

   Seven Mile Beach, Dongara, Australia

b. According to the caption for the photograph above, the "star sand" grains are the shells, called tests, of what organism?

c. This sediment is (circle one): ***lithogenous / biogenous / hydrogenous***

11. Biological Beaches

In many tropical regions, the main material supplied to beaches comes from the dead shells of marine organisms such as clams, snails, corals and other invertebrates. Compare the three beach sand samples here.

Sample 11-1: Cayo Costa, Florida
Sample 11-2: Bahia Coyote, Baja, Mexico
Sample 11-3: Tahiti

a. These beach sands are all (circle one): ***lithogenous / biogenous / hydrogenous***

b. What are the similarities between these beach sand samples?

c. What are the differences?

12. Diatoms and Diatomite (Diatomaceous Earth)

Diatoms are one of the most abundant forms of phytoplankton on Earth; there can be millions of them in a single liter of seawater. Each diatom has a tiny internal shell, called a *test*, which accumulates as part of the sediment on the seabed when the organism dies.

a. Sketch a few of the diatom tests seen through the microscope, illustrating their porous (lots of holes) appearance.

b. The chemical composition of diatom tests is (circle one): ***calcite / silica***
(If you don't remember, read the information about diatoms several pages back.)

c. Where vast numbers of diatom tests accumulate on the seabed, they form a type of sediment called (fill in the blank) **____________________ ooze.**

d. When ooze like this hardens, it forms a distinctive rock called **diatomite** or **diatomaceous earth**. Pick up the samples of diatomite (the white, powdery rock) and examine them. What is most striking to you about this rock? Why do you suppose diatomaceous earth is used for manufacturing high-quality water filters? *(Hint: try putting a drop of water on one of the samples and watch what happens to it after a minute or so.)*

13. Calcium Carbonate ($CaCO_3$) versus Silica (SiO_2)

At this station there are four rock samples: **Limestone, Chalk, Diatomite** and **Chert Nodules.** Please don't mix the samples up for the students coming after you.

a. Notice the fossils in the **limestone.** These once-living organisms made their hard shells out of **calcium carbonate ($CaCO_3$).** Use one drop of hydrochloric acid on the limestone (the acid is dilute and won't burn you). Describe what happens. This "acid test" tells us that the limestone is made of **$CaCO_3$.** In contrast, anything made of **silica (SiO_2)** will not react with acid because silica is chemically stable in acidic conditions.

b. Chemically, the result that you saw with the limestone above is because the acid (H^+) dissolves the $CaCO_3$. Although the strength of the hydrochloric acid you just used makes this chemical reaction occur quite rapidly, it simulates what happens to $CaCO_3$ in a reaction with carbonic acid in seawater. <u>Explain how this reaction is related to what happens to $CaCO_3$ below the CCD</u>. *(Hint: Refer to Figure 2 several pages back.)*

c. Also at this station is a piece of **chalk** and a piece of **diatomite**. They look similar; both are fine-grained, white colored rocks. But chemically they are completely different. One forms from the hardening of **calcareous ooze** (composed of $\mathbf{CaCO_3}$) and the other from the hardening of **siliceous ooze** (composed of $\mathbf{SiO_2}$). Put one drop of acid on each of these samples and observe what happens. Circle the correct options in *italics* below to complete the sentences.

The **CHALK** ***does / does not*** react with acid, indicating it is made of $CaCO_3$ / SiO_2

and forms from the hardening of ***calcareous / siliceous*** ooze.

The **DIATOMITE** ***does / does not*** react with acid, indicating it is made of $CaCO_3$ /

SiO_2 and forms from the hardening of **calcareous / siliceous** ooze.

d. Also at this station is a **chert nodule**. Try to scratch the chert nodule with a steel nail. Which is harder? (circle one): ***nail / chert***

e. What do you imagine would happen to metal drill bits used to drill into the ocean floor when the drills hit a bed of chert?

f. Put one drop of acid on the chert nodule. Based on the reaction, what does this tell you about the chemical composition of chert?

******Before you leave this station, please clean up any wet acid residue with a paper towel******

14. Deep-Sea Sediment I

a. This is a sample of material that recently accumulated on the deep sea floor. Look closely at the particles under the microscope. What type of sediment is this (circle one)? ***lithogenous / biogenous / hydrogenous***

b. The tiny shells (called tests) that you see are known as **foraminifers** (or **forams** for short). The chemical composition of these shells is (circle one): ***calcite / silica***

c. Sketch a few of the foraminifer tests (shells).

d. Would this sample qualify as an "ooze?" (circle one): ***yes / no*** Explain your answer.

e. Would this sample classify as (circle one): a ***calcareous ooze*** or a ***siliceous ooze***?

f. This sample would most likely have formed (circle one): ***above the CCD*** or ***below the CCD*** Explain your answer. *(Hint: look at Figure 4.)*

15. Deep-Sea Sediment II

a. This sediment accumulated on the deep sea floor as tiny particles, having been blown off the continents by <u>wind</u> and carried far out to sea. What type of sediment is this? (circle one): ***lithogenous / biogenous / hydrogenous***

b. What is name of this particular type of sediment? *(Hint: there is only one type of marine sediment deposited by wind.)*

c. Would you expect to see this sediment accumulating below the CCD? Explain your answer. *(Hint: look at Figure 4.)*

16. Turbidity Current Tank

a. How do you think the density of a **turbidity current**—a turbid, flowing mixture of seawater and sediment—will compare to the density of pure seawater? *(Circle your prediction.)*

less dense	***more dense***	***the same density***

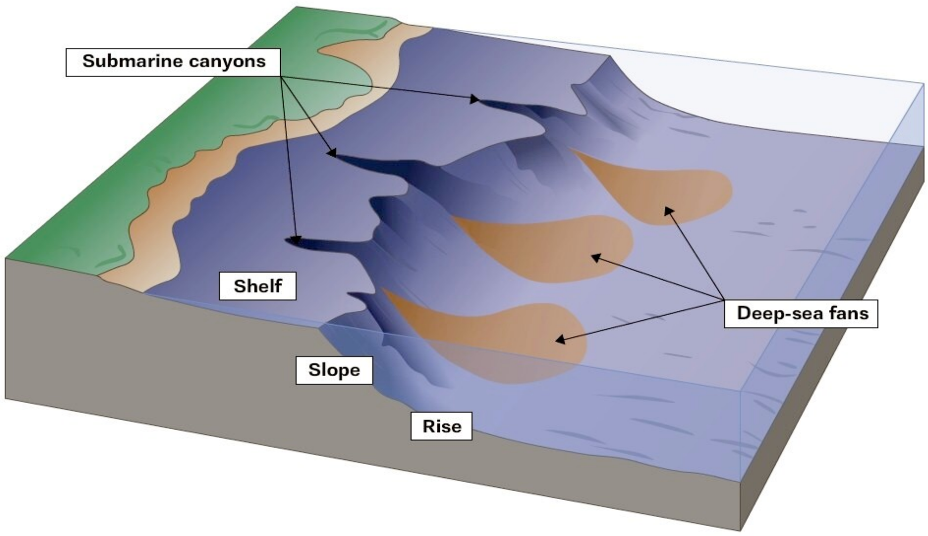
b. Therefore, what will this seawater-sediment mixture do when it flows into the ocean? *(Circle one.)*

flow across the ocean surface	***flow down slope across the ocean floor***	***mix evenly with other ocean water***

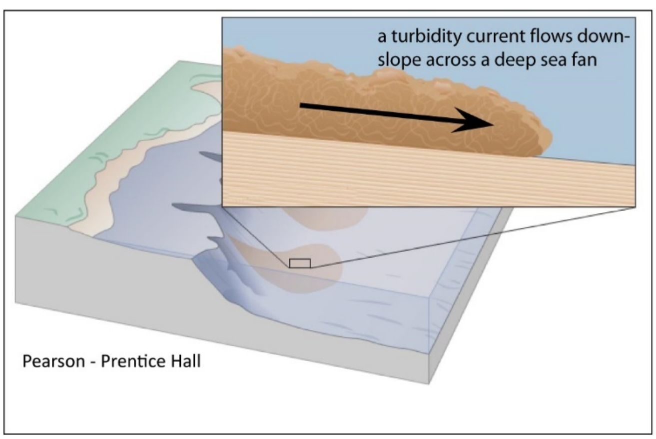
c. Make a turbidity current and watch its movement. On the tank diagram below, draw a simple sketch of the current about half way through its journey. Label on the diagram where the **sand** carried by the turbidity current settled, and where the **mud** settled (or will eventually settle).

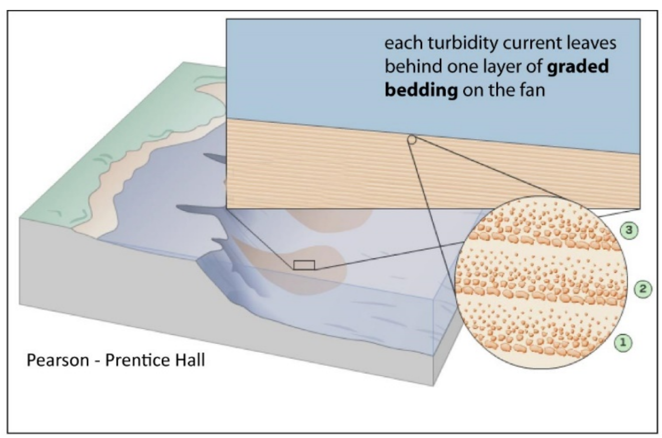
d. Now imagine doing this experiment many times, so that you created a stack of sand and mud layers several inches thick in the tank. Draw on the diagram what you think the layers would look like, labeling the locations of the sand versus the mud, and showing how the slope of the ocean floor would change. *(Note: some areas of the ocean floor would not remain flat as the layers built up.)*

e. On this illustration, <u>three</u> of the regions labeled are represented by the tank demonstration. On the tank diagram above, label three areas of the tank that most closely represent three specific ocean floor regions labeled on the diagram.



As a turbidity current exits a submarine canyon and cruises across a deep sea fan (left hand diagram below), it slows down and loses energy, depositing its load of sediment to form what is called ***graded bedding***. On the right hand diagram below, notice the pattern of particle sizes in the numbered layers. In each layer, notice that the particle sizes change from larger at the bottom to smaller at the top. This is graded bedding. A <u>single</u> turbidity current will leave behind <u>one</u> layer of graded bedding. But over geologic time, hundreds of turbidity currents can pile up many layers of graded bedding on deep sea fans.

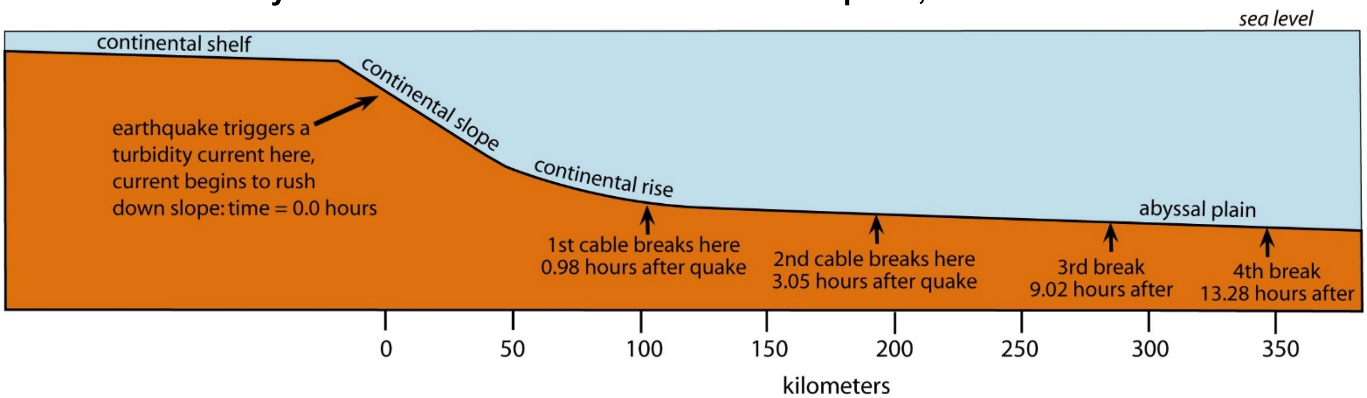




f. Take a scoop of sediment and pour it all at once into the tall glass cylinder. Describe what you see in the layer that forms as the particles settle through the water. How does this relate to turbidity currents producing graded bedding on deep sea fans?

g. In 1929, a large earthquake struck the seafloor south of Newfoundland in the North Atlantic Ocean. The quake triggered a turbidity current that was so powerful that it broke a series of thick undersea telegraph cables as it traveled for many hours down slope. The timing of the broken cables after the earthquake allowed scientists to calculate the current's speed and duration, giving us some of the best evidence we have for exactly how large and powerful turbidity currents can be. Study the diagram and make the calculations to see for yourself.

Turbidity current from 1929 Newfoundland earthquake, North Atlantic Ocean



1. How far (at the least) did the turbidity current travel?___________km. How long did it travel?

___________hours.

2. What was the velocity (in km/hr) of the current between <u>initiation</u> and the <u>first cable break</u>?

_____________km/hr. Convert this to miles per hour (multiply by 0.62 mi/km)

___________mi/hr.

3. What was the velocity (in km/hr) of the current between the <u>first</u> and <u>second</u> cable break?

_____________km/hr. Convert this to miles per hour ____________mi/hr.

4. What was the velocity (in km/hr) of the current between the <u>second</u> and <u>third</u> cable break?

_____________km/hr. Convert this to miles per hour ____________mi/hr.

Think about it: even though the current slowed down a lot as it traveled across the abyssal plain, it still had enough speed and power, even hours later, to break thick undersea cables!

What is your reaction to this astonishing event? (circle all options that apply):

Stupendous! ***Amazing!*** ***Wow!*** ***I love science!***